

Inherent Biophysical Risk Mapping Manual and Methodology – Working Document

Prepared for Bay of Plenty Regional Council

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Disclaimers and Limitations

This report ('Report') has been prepared by WSP exclusively for Bay of Plenty Regional Council ('Client') in relation to development of the methodology for creation of biophysical risk maps for nitrogen, phosphorus, sediment and E.coli for the Waihi and Nukuhou catchments ('Purpose') and in accordance with the Short form Agreement with the Client dated 16.04.2024 (project number 3-9C729.03) and in conjunction with the project BOPRC – Biophysical Risk Maps funded by Access2Experts (project number 3-9C729.02). The findings in this Report are based on and are subject to the assumptions specified in the Report, the Contract, and GIS Toolbox. WSP accepts no liability whatsoever for any reliance on or use of this Report or GIS Toolbox, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

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1 Introduction

There are four main contaminants that can impact surface water and groundwater quality, affecting both swimability and waterway health: nitrogen, phosphorus, sediment and *E. coli*.

Bay of Plenty Regional Council (BOPRC) engaged WSP to develop risk maps for these contaminants, to support their land managers in targeted conversations with landowners on potential mitigation opportunities. The contaminant risk maps will help landowners make on-farm decisions to meet catchment targets under the National Policy Statement for Freshwater Management 2020 (NPS FM-2020). The risk maps developed will be useful to identify “hot spots” or areas of risk for potential contaminant loss, so on-farm actions and mitigation planning can be targeted to achieve the best outcomes for both the farming community and the wider biophysical environment. This project was co-funded by Access2Experts and BOPRC.

The mapping approach combined existing empirical datasets (such as LiDAR, soils, slope, rainfall, presence of waterways, overland flow paths/flow aggregation points and groundwater drainage), to provide high resolution spatial guidance to regional council land managers on the relative risk of contaminant losses via surface water flows and runoff processes for two specific catchments. The intention was to provide a proof of concept and an easily replicable approach for other catchments in the BOP region, and potentially other regions across Aotearoa New Zealand. The risk mapping and methodology document is targeted at regional council staff, their land managers and industry consultants.

Outputs

- Biophysical contaminant risk models in an ESRI ArcGIS toolbox format that are publicly available. The models outputs can be used as base layers for the identification of inherent biophysical risk areas at a farm scale (or best available resolution based on available data sets).
- This ‘methodology guidance document’, describing the approach taken to create the GIS layers – that can be referred to those in other regions who may develop similar contaminant risk information in future. This document has been produced in a draft/working format, to enable ongoing development of the approach.

2 Inherent biophysical risk assessment

2.1 What is inherent biophysical risk mapping?

As described in the Freshwater Farm Plan Regulations: Discussion Document (Ministry for the Environment and Ministry for Primary Industries 2021) the overall risk from contaminants to water quality and freshwater ecosystem results from the interaction of two types of risks: inherent (biophysical) and those stemming from land management practices. Inherent biophysical risk can be defined as the natural characteristics of the land that contribute to contaminant loss.

The risk assessment process, developed by WSP and BOPRC, considers biophysical characteristics of the land such as soil properties, slope, distance from waterways, land cover, etc. to map inherent contaminant risks. The mapping output aims to identify and prioritise the potential risks to guide the choice of actions to avoid, remedy or mitigate those identified risks.

It is important to note that:

- The maps do not consider management risk, farm management practice, mitigations, or the potential adverse effect of on-farm activities (beyond typical land cover).
- The maps do not attempt to quantify contaminant loss or catchment load.

- The maps are not suitable for policy development, regulation, or limit setting.
- The maps can be used by regional councils to have informed discussions with landowners on the management of potential contaminant risk on their land.

2.2 Methodology overview

The biophysical risk maps use readily available spatial datasets to inform on potential risk of contaminant loss from productive land. Creation of the risk maps took into consideration the contaminant flow paths and the characteristics of the landscape that might influence contaminant transport. A multi-criteria analysis approach was taken that integrated an analytical hierarchy process and a weighted overlay analysis, supported by GIS, to develop four geospatial inherent biophysical risk models (one for each contaminant).

2.3 Key biophysical factors, data gathering and gap analysis

The four water contaminants considered in this project were:

- Faecal coliforms (*E. coli*)
- Nitrogen (N)
- Phosphorus (P)
- Sediment (Sed)

First, we identified the key biophysical factors contributing to the generation and transport of each of the contaminants, based on existing literature, experience and expert knowledge. Then the necessary spatial layers were gathered from various sources, including BOPRC's services and open access data services such as MfE, LINZ, LRIS and LENZ, to represent these processes within the model.

In gathering the data and information, we investigated the following:

- Current open-source risk models that determine water contaminant risk for N, P, Sed and *E. coli* based on biophysical risk.
- The availability of the required spatial layers and their geographic coverage.
- The catchment sensitivity for each contaminant, which was provided by BOPRC based on the state of each Freshwater Management Unit.

From our data gathering exercise we noted gaps in the applicability, availability and transparency of existing tools and datasets for farm planning purposes.

When determining the spatial data inventory layers for each contaminant we identified apparent gaps in S-map coverage, for the two catchments selected. This is common across parts of New Zealand for data such as S-map and LiDAR. While the overall preference is to use data from S-map and LiDAR derived elevation, to overcome this the models were developed to ingest information from Fundamental Soil Layers (FSL) to fill the gaps and enable use with other type of elevation data.

There are significant differences in the spatial detail and quality of available overland flow path and stream network datasets between regions. The location and/or order of waterways is an essential input of some of these models and the spatial granularity of this layer will have a significant effect on the risk maps. BOPRC provided a region-specific overland flow path layer, which was used to develop these models.

To capture land cover, the Land Cover Database v5 (released in 2020) was initially identified. However, after discussion with BOPRC it was replaced by the LUCAS 2020 layer as which was a better fit for risk mapping, due its simplified representation of the landscape (12 classes).

It is important to note that the quality and reliability of the model outputs are highly dependent on the quality of the input layers. At this stage, the toolbox can only be applied to catchments with at least partial S-map coverage.

2.4 Establishing criteria

The set of rules and criteria describe the relative risk of contaminant losses under various conditions. During the process of defining criteria, consideration was given to expert knowledge, data gathering outcomes, data inputs from BOPRC, and feedback from stakeholders. Spatial patterns of hydrological connectivity were taken into account as mobilisation pathways, as a function of topography, soil characteristics and land cover. To establish the criteria set a two-step approach was followed.

2.4.1 Step 1. Identification of publicly available GIS layers

The main objective of this phase was to identify the publicly available layers that are relevant and could be used directly.

Table 1 provides the list of open access datasets selected for the biophysical risk models.

Table 1 Summary of the publicly available spatial layers used for risk mapping

Original layer name	ID	Labels	Link to source	Brief description
<i>S-map Nitrogen Leach Susceptibility Aug 2024</i>	1	Smmap N leach susceptibility	Link	The susceptibility of the soil to nitrogen leaching
<i>FSL Soil Drainage Class</i>	2	FSL soil drainage	Link	Soil drainage classes are described and assessed using criteria of soil depth and duration of water tables inferred from soil colours and mottles.
<i>LUCAS NZ Land Use Map 2020 v003</i>	3	LUCAS	Link	LUCAS LUM determines land use classes (12)
<i>Bay of Plenty LiDAR DEM (2019-2022)</i>	4	DEM	Link	Elevation raster data. The recommended spatial resolution is 5 m for optimal performance and visual effect. Although, the models will resample the DEM to any cell size specified
<i>Average annual rainfall (mm), 1972-2016</i>	5	Mean annual rainfall	Link	NIWA interpolated annual rainfall totals, measured at climate station locations across the country, to create a regular 500m resolution grid of average annual (from 1972 to 2016)
<i>FSL Permeability Profile</i>	6	FSL soil permeability	Link	Permeability is the rate that water moves through saturated soil.
<i>Our Land and Water soil loss 2022</i>	7	Donovan's soil loss	Link	Annual soil loss from surface erosion. These maps are the first in the world to include the impact of stock grazing, so provide a more accurate picture of surface erosion susceptibility. The maps can provide estimates of surface erosion susceptibility from different land uses and areas of land. This is useful for understanding the relative contribution of land use at catchment scales.
<i>Highly erodible land (HEL) 2022</i>	8	HEL 2022	Link	Highly erodible land (HEL) refers to land that is very susceptible to erosion. This indicator measures landslide, earthflow, and gully erosion risk across Aotearoa New Zealand using the HEL model. The HEL model identifies land at risk to the main forms of mass-movement soil erosion if it does not have protective woody vegetation.
<i>River Environment Classification 2 (REC2)</i>	9	Waterways	Link	RECV2.5 digital river network, a database of catchment spatial attributes, summarised for every segment in New Zealand's network of rivers.
<i>Catchment outline</i>	10			Provided by BOPRC
<i>S-map Soil Drainage Aug 2024</i>	11	Smmap soil drainage	Link	This layer is a "dissolved" representation of the soil drainage attribute for S-map soils.
<i>S-map soils</i>	12	Smmap soil properties	NA	This polygon layer originates from a combination of S-map soil layers. The layer contains two key attributes for the P risk model: P retention [PRetentionTopsoil] and relative runoff [RelativeRunoffPotential]. This spatial information was provided by Bay of Plenty Regional Council.
<i>LENZ - Acid soluble phosphorous</i>	13	Acid soluble P	Link	Acid soluble phosphorous data layer used in the creation of Land Environments of New Zealand (LENZ)

				classification. This data layer is a measure of how much acid soluble phosphorous is held within the soil. The data defines the level of acid soluble phosphorous based on the soil information (from the NZLRI) and the mapped parent material.
<i>FSL Phosphate Retention</i>	14	FSL P retention	Link	This polygon layer contains phosphate retention attributes. Phosphate retention (P retention) is estimated as weighted averages for the upper part of the soil profile from 0-0.2 m depth and expressed as a percentage.

2.4.2 Step 2. Additional information and derived layers

This step investigated those factors with important contribution to the models and could be sourced from BOPRC or can be derived from the layers identified in Step 1. Descriptions of these layers are provided below.

Catchment outline and sensitivity

Catchment outline and sensitivity is based on the Fresh Water Management Unit (FMU) and assessment of water quality and ecosystem health for that unit. BOPRC identified 13 FMUs that are sensitive and affected by freshwater contaminants (Bay of Plenty Regional Council 2023). BOPRC evaluated each FMU and assigned an indicator representing the scale of change needed to improve water quality and meet environmental outcomes (Figure 1). For more information contact BOPRC.

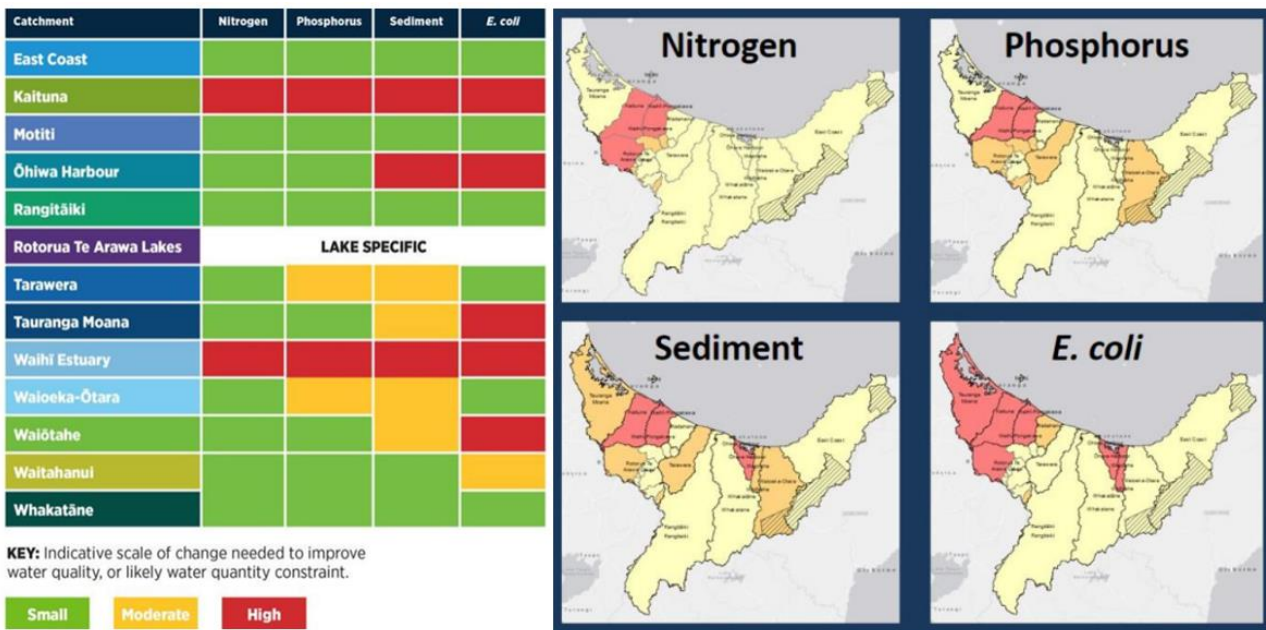


Figure 1 Catchment sensitivity (scale of change required) for the 13 FMUs in the Bay of Plenty Region (supplied by BOPRC).

The models require a surface water catchment outline layer with indicators of scale of change required for each contaminant. This information was provided by BOPRC. The 'Catchment outline and sensitivity' feature class must contain this information for each contaminant in separate fields as strings in the attribute table (e.g. Table 2)

Table 2 Required fields of the catchment outline and sensitivity layer

Shape	Catchment	N_sen	P_sen	Sed_sen	EColi_sen
Polygon	Waihi Estuary	High	High	High	High

Landform categories

The landform layer was created by using a geoprocessing tool that is part of the Spatial analyst toolbox. The Geomorphon Landforms tool computes the geomorphon pattern of each cell of an

input surface raster and classified calculated geomorphons into common landform types, such as flat, peak, ridge, shoulder, spur, slope, hollow, footslope, valley, and pit (Jasiewicz and Stepinski 2013). A geomorphon is a representation of landscape based on elevation differences within the surrounding area of a target cell. The terrain is considered flat if the difference between elevation angles is less or equal to 3 degrees.

Waterways

The waterways layer is essential for three models (E.coli, Sed and P models). This layer must be a polyline feature class and should cover the extent of the entire catchment. While the E. coli model only requires the waterways layer as geometric features and the model can run without stream order information, for the Sed and therefore the P model, a stream order attribute is also required. The stream order field should be integer type, typically with values between 1-8 (e.g. Table 3). The waterways layer is used to calculate proximity expressed by Euclidean distance.

Table 3 Example of the stream order field in the waterways layer's attribute table

Shape	ObjectID	S_ORDER
Polyline	74	1
Polyline	75	3

2.5 Scoring of sub-criteria

After the main criteria and the most relevant attributes were selected, they were divided into sub-criteria. Since the selected input layers and their attributes were presented in various formats, such as continuous and categorical, with different ranges and options, the attributes were converted into a common scoring scale which allowed their relative comparison. A scale of 1-5 was chosen and each criterion was assigned a score with the same meaning between layers, i.e., low values represent low contribution to the given risk, while factors with high scores are major risk contributors.

An example of how these scores were assigned for the main criteria of soil drainage and its sub-criteria in relation to their influence on *E. coli* risk are presented in Table 4. As default values, the Drainage attribute of this layer classifies the soil into 5 categories (or sub criteria) indicating the likelihood of seasonal wetness. These sub-criteria were passed through a scoring process to assign a risk score. The process was driven by expert opinion and understanding of the role of each criterion in each risk profile. See the Appendix for the individual scoring tables.

Table 4 Example of assigning sub criterion scores

Main criteria	Smap - Soil drainage				
Sub criteria	Well Drained	Moderately Well Drained	Imperfectly drained	Poorly Drained	Very Poorly Drained
Risk score	1	2	3	4	5
	Very low	Low	Medium	High	Very high

2.6 Multi-criteria analysis

A multi-criteria analysis (MCA) approach was used to create the biophysical risk maps. An MCA is a collection of techniques that transforms and combines geographical data for decision making by using defined criteria sets and consists of several steps.

2.6.1 The Analytical Hierarchy Process (AHP)

AHP is a structured ratio scale prioritisation technique, commonly used to assist with generating weights for each criterion or input layer (Wind and Saaty 1980). AHP involves breaking down a complex problem into a hierarchy of more easily comprehended sub-problems, each of which can be analysed independently.

AHP is a widely accepted technique for spatial problems where the number of input layers is relatively low, such as land suitability analysis, land use planning, site selection and risk assessments (Topuz and Deniz 2023). AHP was applied to this geospatial analysis by

implementing the following key steps which were informed by expert knowledge and published literature.

2.6.1.1 Structure of hierarchy

The risk assessment problem was broken down into sub-criteria that considered factors such as land cover, terrain steepness, proximity to hydrological features, soil classifications such as drainage, susceptibility to N leaching, and other characteristics.

2.6.1.2 Pairwise comparison and importance setting

Pairwise comparison determines the relative importance of different attributes or criteria with respect to the risk definition. The criteria pairs were compared on a scale of 1-9 proposed by (Saaty 1990), where 1 indicates equal importance and 9 indicates extreme importance of one criterion over another (Table 5). This scoring approach allowed the ranking of each spatial layer on an absolute scale and enables the calculation of cumulative values for a group of input layers. The criteria are organised into a matrix in which each criterion has its own row and column. The resulting pairwise comparison matrices for each contaminant are shown in the Appendix.

Table 5 The fundamental scale adopted from (Saaty 1990) to assess how much one input layer is more dominant than the other.

Value	Description	Explanation
1	Equal importance for both input layers	Two input layers contribute equally
3	Moderate importance of one element over another	Experience and judgement favour one element over another
5	Essential or strong importance	Experience and judgment strongly favour one criterion over another
7	Very strong importance	An element is strongly favoured
9	Extreme importance of one element over another	An element is dominant the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed

2.6.1.3 Criteria weight calculation

The weighting for each data input layer were derived from the pairwise comparison matrix reflecting the relative importance or weighting, i.e. how much each input layer will factor into the risk mapping. This was done by calculating the geometric mean, then normalising it. These steps ensure that the resulting weights take a value between 0-1, and the sum of all of the weights equals to 1. The weights can also be interpreted as percentage, i.e., a weight of 0.2 means that a given input layer carries 20% of the contribution to the overall risk profile.

2.6.2 Weighted overlay analysis

In the core of this process, a weighted overlay analysis was completed for E. coli, N, and P risk mapping by combining the criteria layers and their weights to produce a risk map as illustrated in Figure 2A (below). The risk index is calculated as the sum of the factor values multiplied by the weight.

2.6.3 Maximum value overlay

In the Sed model, the raster overlay with the maximum value operation, or simply maximum value overlay process, was applied instead of a weighted sum approach (Figure 2B). In this operation, three raster layers were overlaid, and for each cell location, the highest value among the corresponding cells in the input layers was selected and assigned to the output layer. As the input layers represent risks from various erosion processes, the maximum value overlay calculation helps to extract the most dominant process and thereby the most significant value.

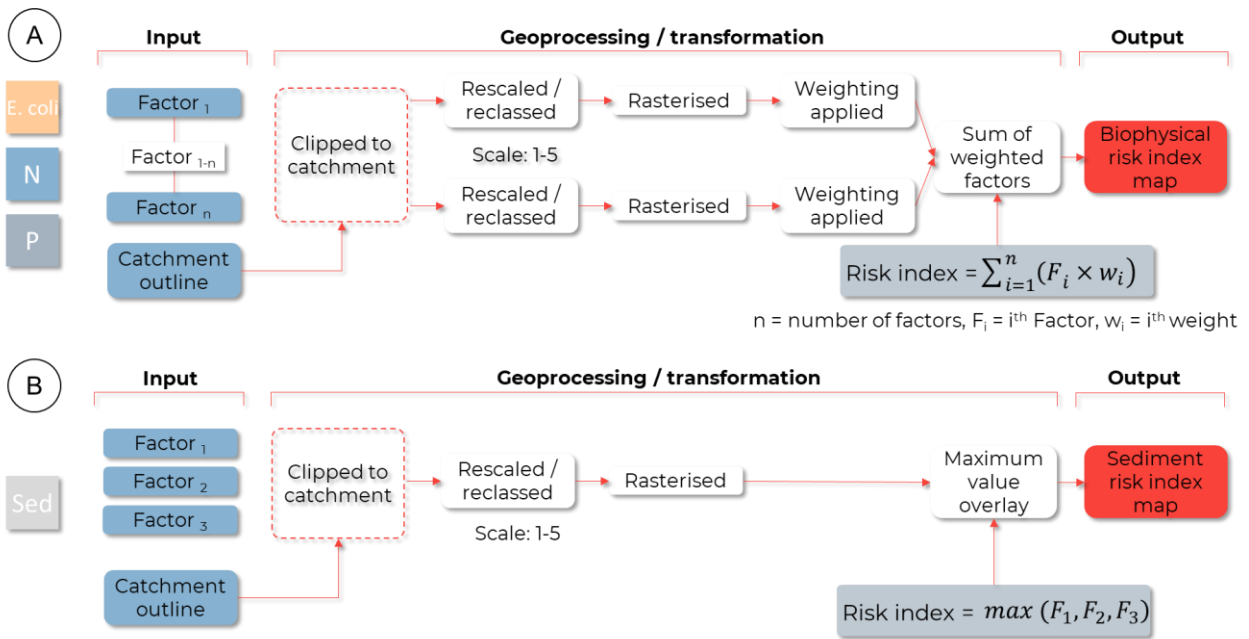


Figure 2 Illustration of the geoprocessing workflows for the four contaminants.

The factors, i.e. the input data layers, were processed in ArcGIS ModelBuilder by chaining together sequences of geoprocesses and transformations. Depending on the risk model and the factor, these steps could include, clipping, deriving additional factors, filtering by attributes, resampling, reclassification, format conversion, standardisation, normalisation, assigning weights, snapping raster, calculating weighted sum, etc.

2.7 Biophysical risk model descriptions

2.7.1 E. coli risk

The E. coli model indicates the potential risk of faecal coliforms reaching surface water bodies. The factors we determined important to estimate E. coli risk were:

- Catchment sensitivity to faecal coliforms (provided by BOPRC).
- The likelihood of runoff (S-map soil drainage or FSL permeability).
- The predominant land cover (to indicate the presence of animals as a faecal coliform source).
- The position in the landscape, flatter and valley-bottom areas more likely to convey coliforms than ridges.
- The proximity to mapped or potential surface water bodies.
- The amount of rain falling on the land.

The sub-criteria, the associated weights and the model concept are presented in *Figure 3*.

Layer	Very Low	Low	Medium	High	Very High	Weight
Catchment sensitivity - E. coli	Small		Medium		High	0.31
LUCAS land use 2020	Refer to table in Appendix					0.24
Annual accumulated rainfall (mm)	<1100	1100-1499	1500-1999	2000-3000	>3000	0.04
Smap soil drainage / FSL Permeability	Refer to table in Appendix					0.15
Proximity to waterways	1	2	3	4	5	0.16
Geomorphon landforms	Refer to table in Appendix					0.10

E. coli risk model concept

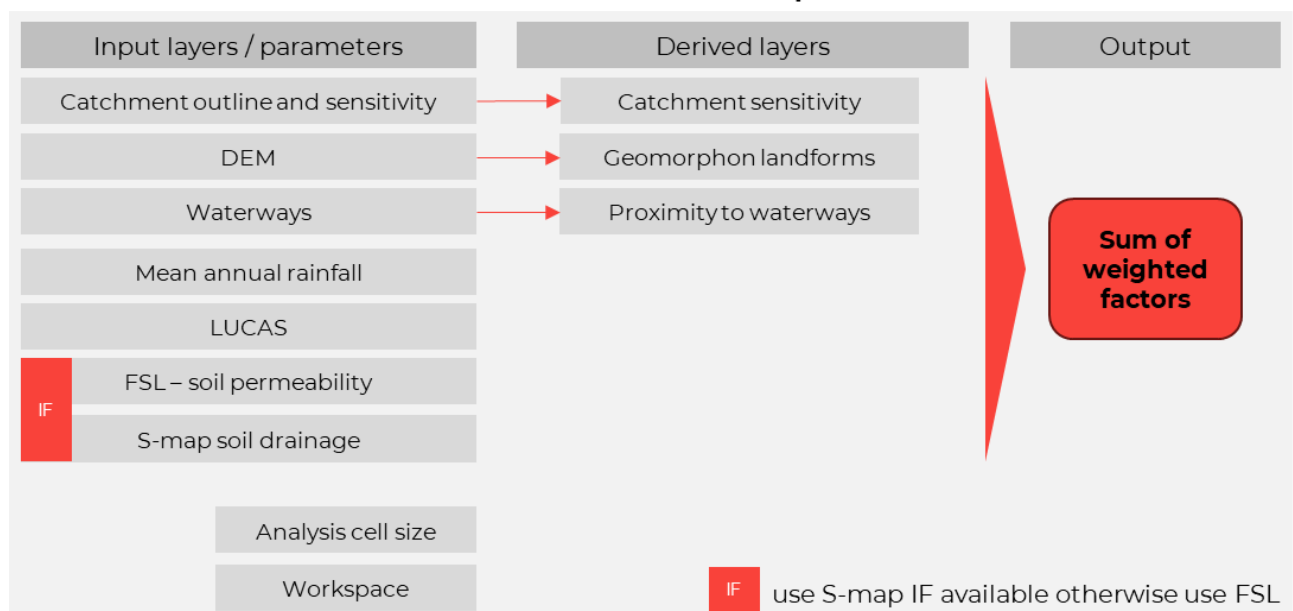


Figure 3 The simplified structure of the sub-criteria set with weights and a diagram of the E. coli risk model structure.

2.7.2 Nitrogen leaching risk

The nitrogen leaching model indicates the potential risk of nitrogen leaching through the soil profile to groundwater. The factors determined as important to estimate nitrogen leaching risk were:

- Catchment sensitivity to nitrogen leaching (provided by BOPRC).

- The likelihood of the soil profile to leach nitrogen (S-map N leaching risk).
- The predominant land cover (to indicate the presence of animals or fertilizer use).
- The position in the landscape, flatter areas being more likely to accumulate nitrogen than steeper areas.
- The amount of rain falling on the land.

The sub-criteria, the associated weights and the model concept are presented in Figure 4.

Layer	Very Low	Low	Medium	High	Very High	Weight
Catchment sensitivity N Leaching	Small		Medium		High	0.31
S-map N leaching risk / FSL Soil Drainage	Refer to table in Appendix					0.34
LUCAS Land use 2020	Refer to table in Appendix					0.19
Slope (in degrees)	<15	15+	7-15	0-7	> 0	0.10
Annual accumulated rainfall (mm)	<1100	1100-1499	1500-1999	2000-3000	>3000	0.05

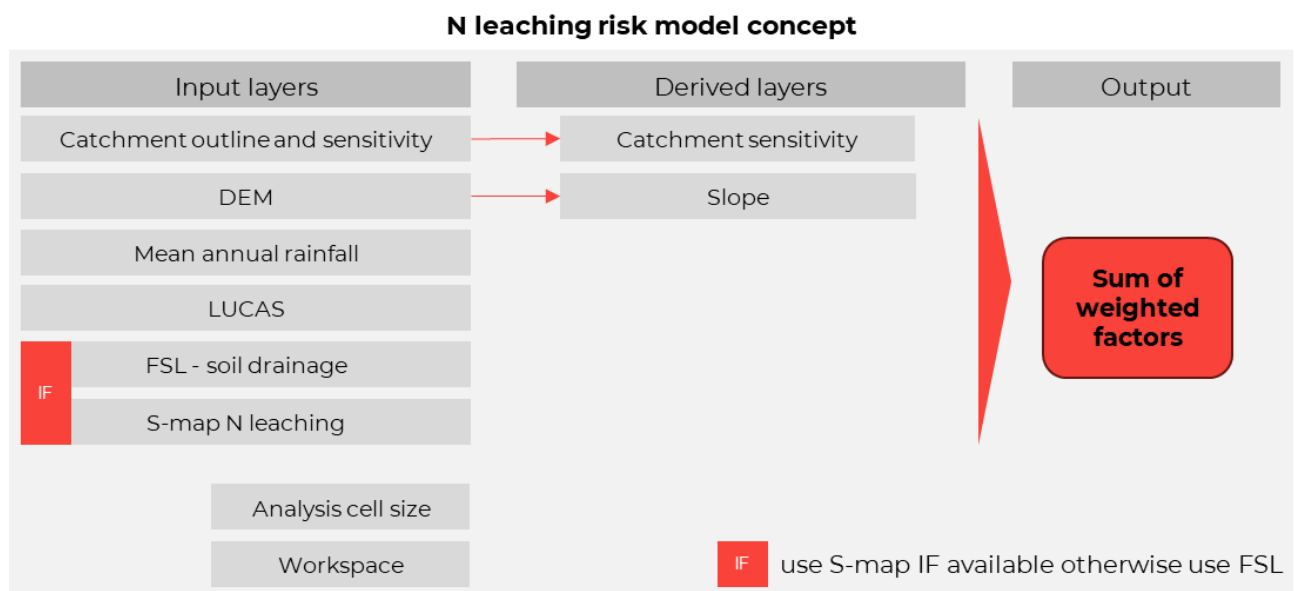


Figure 4 The simplified structure of the sub-criteria set with weights and a diagram of the N leaching risk model structure.

2.7.1 Phosphorous risk

The phosphorus model indicates the potential risk of phosphorus reaching surface water bodies. The factors determined as important to estimate phosphorus risk were:

- Catchment sensitivity to phosphorus (provided by BOPRC).
- The Sed risk model
- The likelihood of runoff (S-map runoff potential or FSL soil drainage).
- Soil phosphorus retention (S-map or FSL).
- Acid soluble P (to account for potential high-P parent material).
- Land slope.
- The amount of rain falling on the land.

The sub-criteria, the associated weights and the model concept are presented in Figure 5.

Layer	Very Low	Low	Medium	High	Very High	Weight
Catchment sensitivity – P risk	Small		Medium		High	0.25
Sed risk	1-				5	0.24
Smap P retention / FSL P retention	Refer to table in Appendix					0.17
Acid soluble P	1	2	3	4	5	0.11
Slope (in degrees)	0 - 5	5 - 10	10 - 25	25 - 45	>45	0.09
Smap runoff potential / FSL soil drainage	Refer to table in Appendix					0.09
Annual accumulated rainfall (mm)	<1100	1100-1499	1500-1999	2000-3000	>3000	0.05

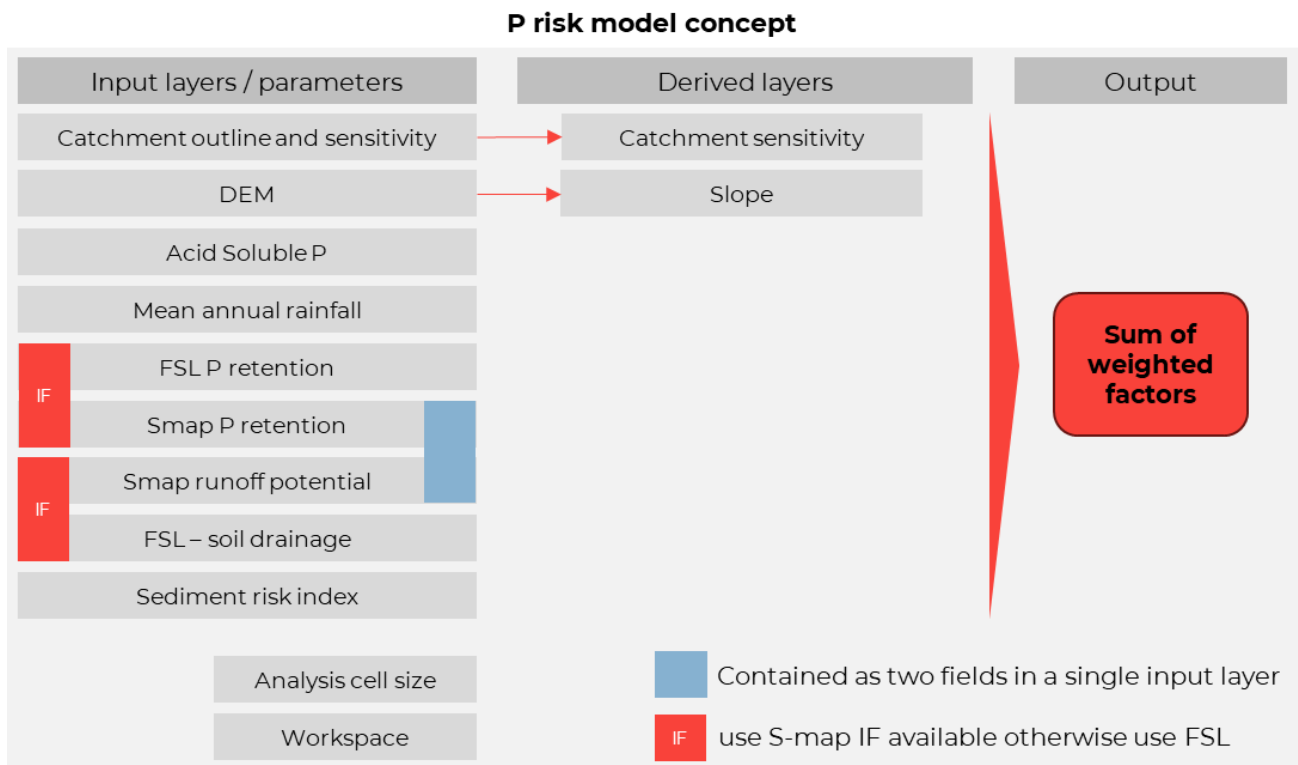


Figure 5 The simplified structure of the sub-criteria set with weights and a diagram of the P risk model structure.

2.7.1 Sediment risk

The Sed model indicates the potential risk of sediment reaching surface water bodies. Numerous models have been produced to estimate erosion and sedimentation generating processes for

New Zealand landscapes. We selected the Highly Erodible Land (HEL) model to estimate the areas potential to be subject to large erosion events, as well as the surface erosion maps published by Our Land and Water and described in Donovan (2023). To account for stream bank erosion, the waterways layer was used to create a stream bank erosion risk buffer as an approximation of stream bank erosion risk. The process was driven by the stream order attribute.

In the Sed model, the maximum value overlay process was applied instead of a weighted sum approach. In this operation, three raster layers were overlaid, and for each cell location, the highest value among the corresponding cells in the input layers was selected and assigned to the output layer. As the input layers represent risks from various erosion processes, the maximum value overlay calculation helps to extract the most dominant process and thereby the most significant value.

The sub-criteria, the associated weights and the model concept are presented in Figure 6.

Layer	Very Low	Low	Medium	High	Very High	Process
HEL Woody/HEL LCDB 2018 (HEL = Highly Erodible Land)	Refer to table in Appendix					Take the maximum value from the three input raster layers.
Soil loss from surface erosion (Donovan 2022)	Refer to Figure 7					
Streambank erosion risk buffer – stream order			Str order: 1, 2, buffer 5m	Str order: 3, 4 buffer 10m	Str order: ≥5 buffer 15m	

Sediment risk model concept

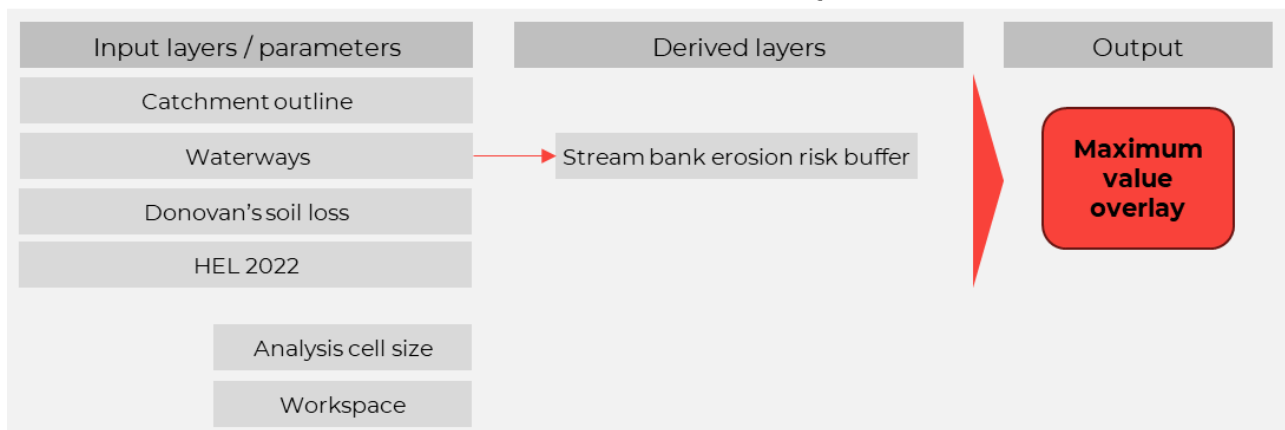


Figure 6 The simplified structure of the sub-criteria set with weights and a diagram of the sediment risk model structure.

A mathematical transformation function was implemented to rescale the Donovan's soil loss raster values to a continuous 1-5 scale. However, as the rescaling was not a linear conversion, the large transformation function available in ArcGIS Pro was chosen. An illustration of the shape of this function and the selected parameters are provided in Figure 7. More information on the mathematical formula behind this function is available on the software documentation website ([ArcGIS Pro documentation](#)).

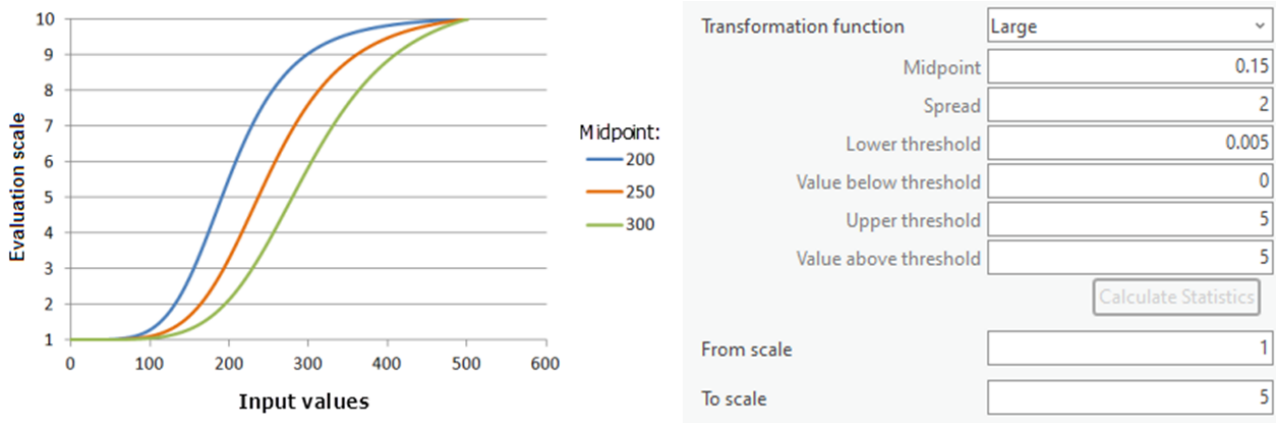


Figure 7 The specifications of the transformation function to rescale Donovan's soil loss layer

3 Geospatial tool description

The IBRM toolbox has been developed to assist with the evaluation of the inherent biophysical risks associated with the land at the farm scale. The previously described sequences of geoprocessing steps have been wrapped into an ArcGIS ModelBuilder toolbox using ArcGIS Pro (version 3.3.0).

Note: Other versions of ArcGIS have not been tested for support.

The *IBRM toolbox package* includes

- The IBRM_toolbox_1.0.atbx

The toolbox file contains 4 geoprocessing models

- Three file geodatabase files as supplementary materials

- IBRM workspace.gdb,

This file geodatabase can be used during modelling to store the intermediate layers as well the output layers (optional, you can use your own workspace instead)

- IBRM_risk_map_examples.gdb

It contains 8 risk maps for two different pilot catchments. These can be visualised to explore how the output might look like.

- IBRM_supporting_layers.gdb

The file geodatabase contains all the required layers to run the models on the pilot catchments and some of the required layers for the for the wider Bay of Plenty region. The users will need to prepare and download all required layers as per the specifications provided in this document to be able to run the model outside of the Bay of Plenty Region.

- IBRM manual and methodology.pdf

A documentation to help with tool implementation.

Once the toolbox folder is opened, the file structure should look similar in your file explorer and in ArcGIS Pro Catalog (Figure 8).Figure 1

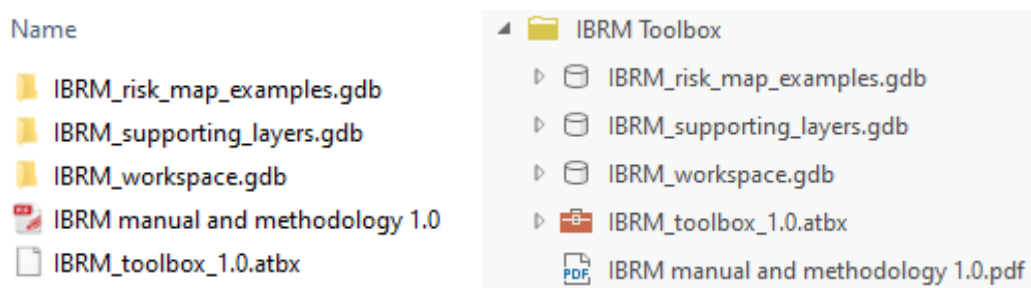


Figure 8 A Windows file explorer (left) and ArcGIS Catalog (right) view of the toolbox package

Note: new updates and version of the publicly available layers may have been released since the development of the toolbox. Check for attribute naming and consistency when using the new versions of the publicly available datasets.

3.1 “How to” guide

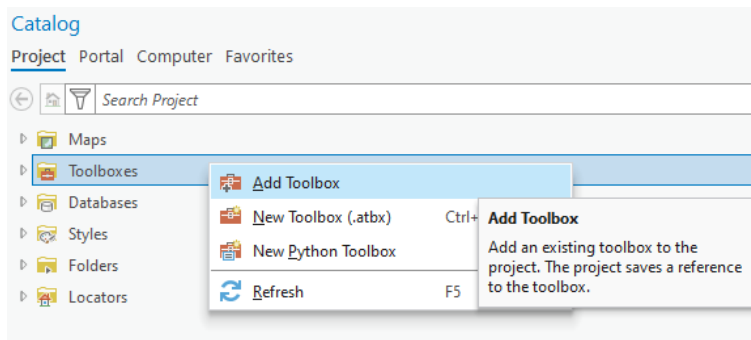
3.1.1 System and software requirements:

- ArcGIS Pro
- Spatial Analyst extension

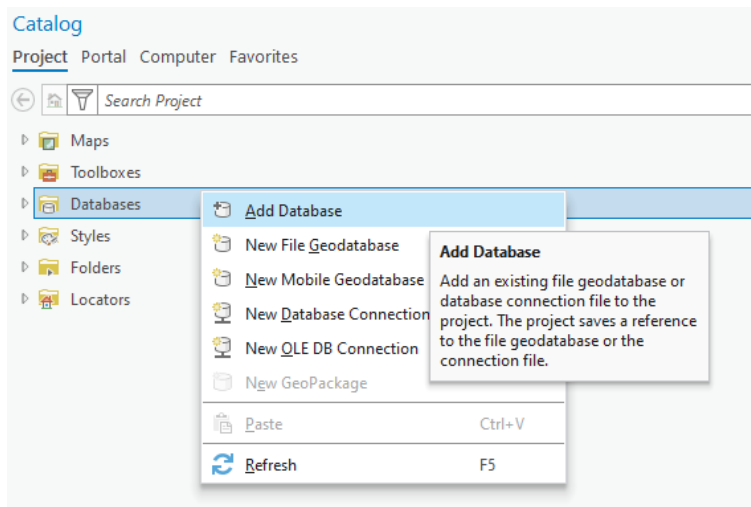
3.1.2 Getting started with the IBRM toolbox

Connect to the toolbox

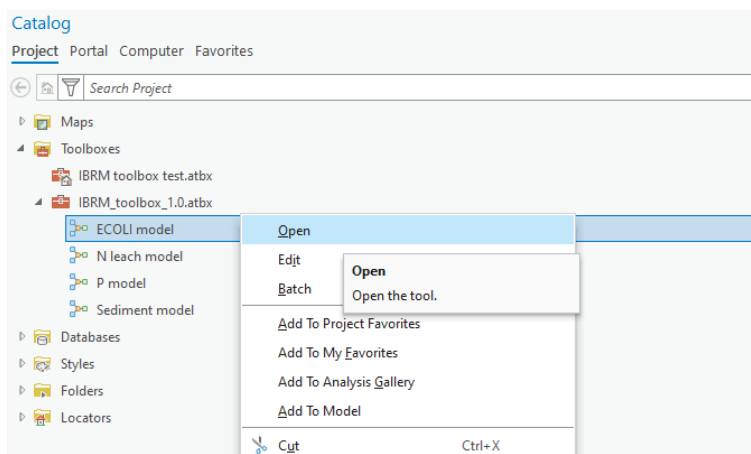
1. In ArcGIS Pro, open an existing project or create a new one.
2. Open the Catalog pane/view and add the *IBRM toolbox* by navigating to the IBRM Tools folder



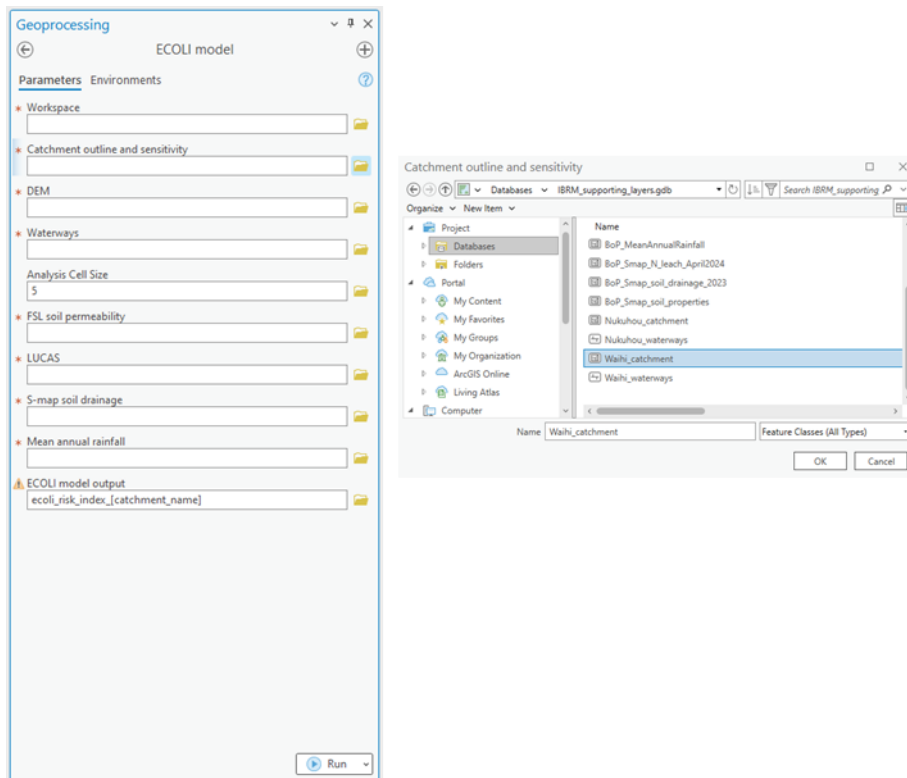
3. Add the provided IBRM mapping file geodatabases to the project (optional)



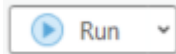
4. Open a risk modelling tool from the toolbox.



- Browse / select / change the input layers, parameters and the risk map naming and file location. You can either use your own workspace or the provided IBRM_workspace.gdb file to manage intermediate layers and the output.



- Click Run to create the risk map.



Follow the Steps 4-6 to run other models.

Note: Running the risk models can take a while depending on catchment size, spatial resolution of input DEM, the complexity of the waterways layer and the computer specs. For reference, E. coli mapping for a catchment area of 320 km² was completed in 68 seconds with a 5m LiDAR DEM as input, running on a laptop with 32 GB RAM, 12th Gen Intel i7 2.1 GHz and an NVIDIA RTX A1000 Laptop GPU.

4 References

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- Jasiewicz, Jarosław, and Tomasz F. Stepinski. 2013. 'Geomorphons — a Pattern Recognition Approach to Classification and Mapping of Landforms'. *Geomorphology* 182 (January):147–56. <https://doi.org/10.1016/j.geomorph.2012.11.005>.
- Ministry for the Environment, and Ministry for Primary Industries. 2021. 'Freshwater Farm Plan Regulations: Discussion Document.' ME 1577. Wellington: Ministry for the Environment.
- Saaty, Thomas L. 1990. 'How to Make a Decision: The Analytic Hierarchy Process'. *European Journal of Operational Research* 48 (1): 9–26. [https://doi.org/10.1016/0377-2217\(90\)90057-I](https://doi.org/10.1016/0377-2217(90)90057-I).
- Topuz, Mustafa, and Mehmet Deniz. 2023. 'Application of GIS and AHP for Land Use Suitability Analysis: Case of Demirci District (Turkey)'. *Humanities and Social Sciences Communications* 10 (1): 115. <https://doi.org/10.1057/s41599-023-01609-x>.
- Wind, Yoram, and Thomas L. Saaty. 1980. 'Marketing Applications of the Analytic Hierarchy Process'. *Management Science* 26 (7): 641–58. <https://doi.org/10.1287/mnsc.26.7.641>.

5 Appendix

S-map Soil Drainage Dec 2023

Drainage	E. coli score
<i>Well Drained</i>	1
<i>Moderately Well Drained</i>	2
<i>Imperfectly drained</i>	3
<i>Poorly Drained</i>	4
<i>Very Poorly Drained</i>	5

LUCAS NZ Land Use Map 2020 v003

LUCID_2020	N score	P score	Sed score	E. coli score
<i>71 - Natural Forest</i>	1	1	1	1
<i>72 - Planted Forest - Pre 1990</i>	1	1	1	1
<i>73 - Post 1989 Forest</i>	1	1	1	1
<i>74 - Grassland - With woody biomass</i>	3	3	3	3
<i>75 - Grassland - High producing</i>	5	5	5	5
<i>76 - Grassland - Low producing</i>	4	4	4	4
<i>77 - Cropland - Orchards and vineyards (perennial)</i>	5	3	3	3
<i>78 - Cropland - Annual</i>	4	3	3	3
<i>79 - Wetland - Open water</i>	1	0	0	0
<i>80 - Wetland - Vegetated non forest</i>	1	0	0	0
<i>81 - Settlements or built-up area</i>	1	5	5	5
<i>82 - Other</i>	0	0	0	0

Geomorphon landforms

Landform types	Landform ID	N score	P score	Sed score	E. coli score
<i>flat</i>	1	5	4	4	4
<i>peak</i>	2	1	2	2	2
<i>ridge</i>	3	1	2	2	2
<i>shoulder</i>	4	3	3	3	3
<i>spur</i>	5	1	2	2	2
<i>slope</i>	6	2	5	5	3
<i>hollow</i>	7	3	1	1	1
<i>footslope</i>	8	3	4	4	4
<i>valley</i>	9	3	5	5	5
<i>pit</i>	10	3	1	1	1

FSL soil drainage

DRAIN_CLAS	Label	N score	P score	Sed score
T		0	0	0
r		0	0	0
q		0	0	0
M		0	0	0
l		0	0	0
i		0	0	0
e		0	0	0
B		0	0	0
5	Well drained	3	1	1
4	Moderately well drained	3	2	2
3	Imperfectly drained	2	3	3
2	Poorly drained	1	4	4
1	Very poorly drained	1	5	5

FSL Permeability Profile

PERMEABILI	E. coli score
estu	0
ice	0
lake	0
NA	0
quar	0
rive	0
town	0
S	5
S/M	4
M/S	4
R/S	3
M	3
M/R	2
R/M	2
R	1

HEL Woody NI 2022

Descriptor	Sed score
Land	1
Water	0
Watercourse bare ground	0
High landslide risk - to stream	5
High landslide risk - not to stream	3
Moderate earthflow risk	4
Severe earthflow risk	5
Gully risk	5
Woody vegetation	0

S-map P retention

pretentiontopsoil P score

0-20	5
20-40	4
40-60	3
60-80	2
80-100	1

S-map relative runoff potential

RelativeRunoffPotential P score Sed score

VH	5	5
H	4	4
M	3	3
L	2	2
VL	1	1

FSL P retention

PRET_MID P score

0-20	5
20-40	4
40-60	3
60-80	2
80-100	1

Acid Soluble P

Class P score

Very low	0-7	1
Low	7-15	2
Moderate	15-30	3
High	30-60	4
Very High	60-100	5

Smmap N leach susceptibility

Nleach N score

Very low	1
Low	2
Medium	3
High	4
Very High	5